Nanocrystalline Diamond pn - Structure grown by Hot-Filament CVD

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Abstract

Conducting diamond is generally p-type doped by boron, n-type doping still being hindered by very high activation energies. Thus, the lack of shallow donor doping has prohibited the realization of diamond bipolar structures of technical relevance. In contrast, ultra-nano-crystalline diamond (UNCD) can be n-type doped with low activation energy [1]. In the past, such n-type UNCD films have been deposited onto p-type single crystal diamond resulting in highly rectifying pn-diode characteristics [2].

The question addressed in this investigation is the following: can n-type conduction also be obtained in NCD layers with grain sizes in the order of 10 nm up to 100 nm, which is a commonly used material grown by MPCVD as well as HFCVD on large area surfaces. In contrast to UNCD, where Ar and C_2 are mostly used as precursors, NCD is normally grown by CH_4-chemistry and α-parameter engineering. Nitrogen is used in some cases, however mostly to adjust the α-parameter, not for n-type doping. If n-type doping of NCD can be obtained, this may allow in conjunction with boron doping to fabricate pn-junctions entirely in NCD.

In this study such a pn-doped structure has been grown by HFCVD (on Si). After nucleation by BEN a highly insulating NCD layer has been grown in a $H_2/CH_4/N_2$ mixture, serving as buffer layer. A p^+ contact layer was then deposited in a H_2/CH_4 mixture with boron added as trimethyborate. The active layer was created by a nominally undoped i-layer with an un-intentional boron background concentration in the order of 10^{18} cm^{-3}. This active layer has then been covered with a heavily nitrogen doped NCD layer.

Hall measurements of the heavily n-type doped NCD layer resulted in clear n-type conduction with an electron concentration of 3×10^{19} cm^{-3} and an electron mobility of approx. 7 cm^2/Vs, similar of what has been observed for UNCD. Hall analysis of the p^+ contact layer resulted in a hole concentration of approx. 6×10^{20} cm^{-3} and a hole mobility of approx. 0.6 cm^2/Vs. Thus in fact a pn-junction has been created. First diode IV-characteristics are indeed rectifying (see fig. 1). In attempt to compare these characteristics with the case of a single-crystal / nano-crystal junction [2] will be presented.

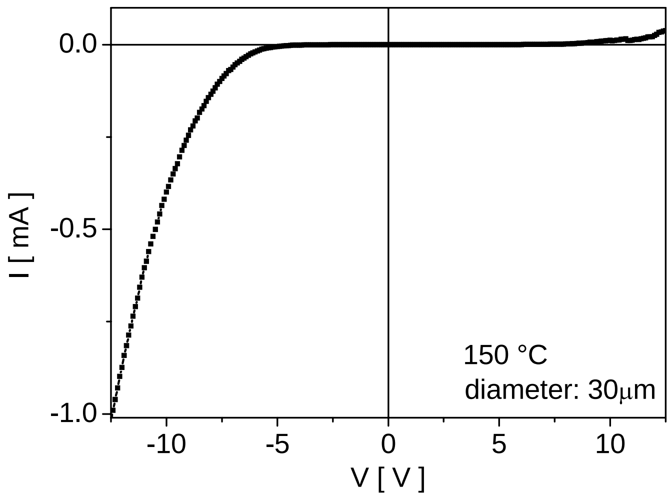

Figure 1. IV characteristics of NCD pn structure

References

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